LOW FREQUENCY OBSERVATIONS OF PECULIAR RADIO GALAXIES

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Motivation

Radio galaxies strikingly produce collimated jets from kiloparsec to megaparsec scale. These jets are powered by relativistic particles and magnetic field emanating from the core of active galactic nuclei. With new highly resolved deep sky surveys, more radio galaxies with interesting morphologies are discovered such as S-, X- and Z-shaped sources. Radio galaxies with such twisted jets underlie a complex and dynamic mechanism taking place at their cores. With many leading theories explaining the formation of these peculiar structures, there is a lack of sufficient evidence in support of either of them. We intend to probe the distorted jet/lobe morphology in order to understand the physical conditions at the central supermassive black hole of such host galaxies.

Here we present new 610 MHz data of a sample of S-shaped sources from dedicated low frequency uGMRT observations.

Models of Precession

A range of possible models for this reorientation or precession connected to the changing direction of the spin axis have been proposed including :

1. Reorientation of the jets due to the presence of another supermassive black hole in the same nucleus [1]

- OJ 287 is a famous example of a blazar constituting of a binary black hole system.
- The presence of a massive black hole in the neighborhood of a primary supermassive black hole in the center of a galaxy can lead to precession of jets as the black holes revolve around to coalesce with each other.

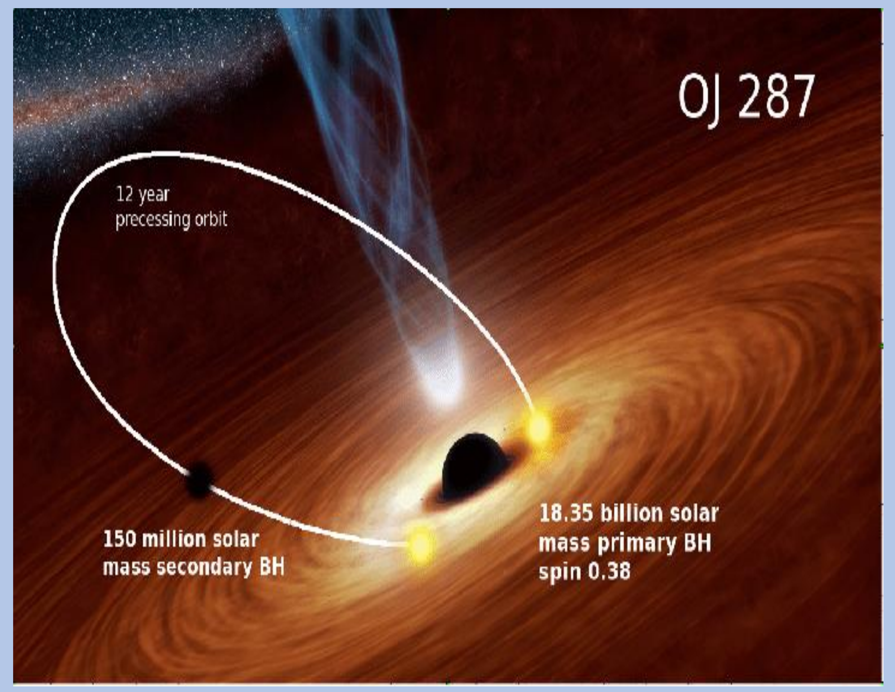

Fig 1. Artistic illustration of the binary black hole system in OJ 287 [2]

2. Surrounding tilted accretion disk[6]

- Misalignment between the accretion disk and the black hole spin is expected to be common among active galactic nuclei.
- The disk - jet system undergoes Lense - Thirring precession[5] and approaches alignment.

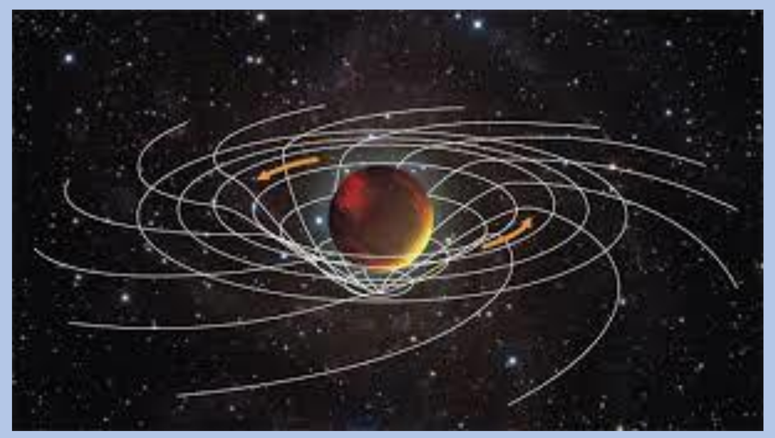

Fig 2. Twisted space time metric due to Lense-Thirring precession around a rotating mass. Credits - Annie Rosen

Acknowledgement

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Low Frequency Radio Observations

- A sample of five promising candidates showing S-shape radio morphology were observed with the upgraded Giant Metrewave Radio Telescope (uGMRT) at 610 MHz.
- The selection of these sources were based on the clear morphological precision denoting an S- shape from archival radio maps.
- Below are shown three of the sample sources observed with uGMRT at 610 MHz.
- The diffuse emissions are well mapped at the low radio frequency along with the current direction of the jets.

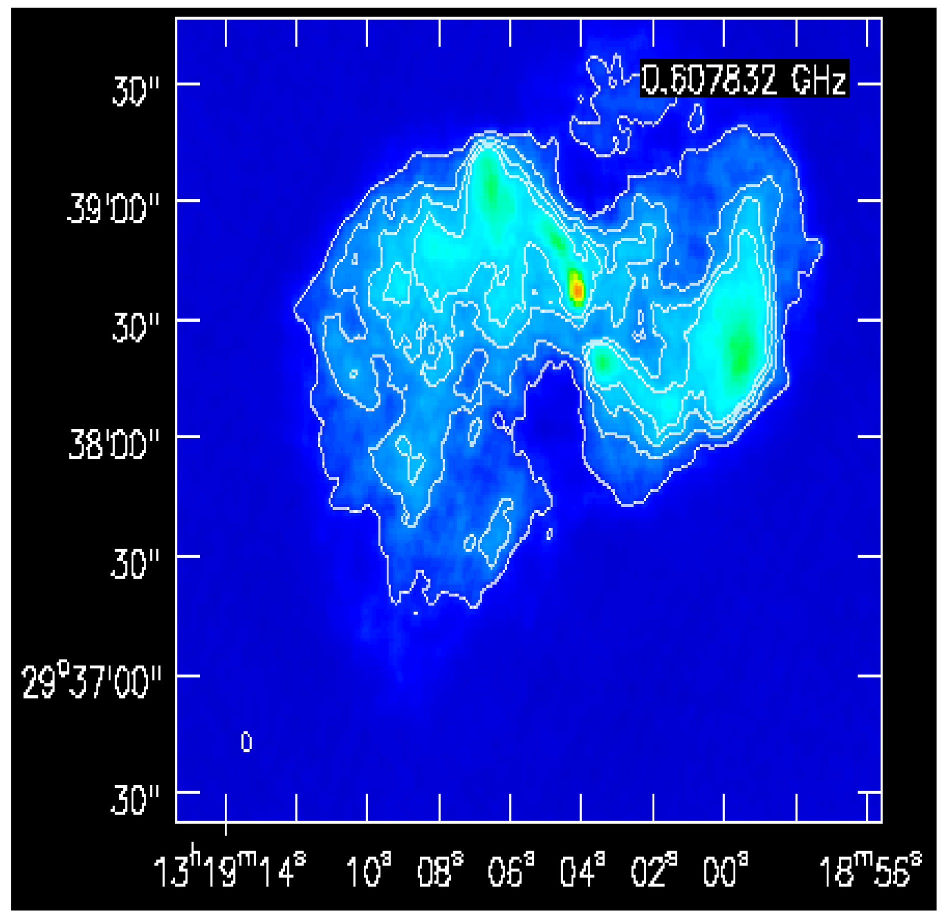

Fig 3. 610 MHz map of J1319+2938

- In Fig 3, the north-west and south- east protrusion showing the extended emission, traces an horizontal S-shape. The core and the hotspots indicate the recent direction of jets.
- The source J1319+2938, with associated redshift z = 0.0728 has angular size of 3'.
- The total flux of the source at 610 MHz is 2.05 Jy.
- The total flux of the diffuse emission is 0.6 Jy.
- The spectral index of the diffuse emission between 610 MHz and 1400 MHz is 1.1, indicating a steep spectrum.

- In Fig 4, the core and the hotspots indicate the current direction of jets while the diffuse emission making a C-shaped arc around the ends of both of the lobes in the north-east and south-west direction trace an S-shape morphology.
- The source J1353+2809, with associated redshift z = 0.4 has angular size of 1.3'.
- The total flux of the source at 610 MHz is 0.5 Jy.
- The total flux of the diffuse emission is 0.2 Jy.
- The spectral index of the diffuse emission between 610 MHz and 1400 MHz is 1.4, indicating very steep spectrum.

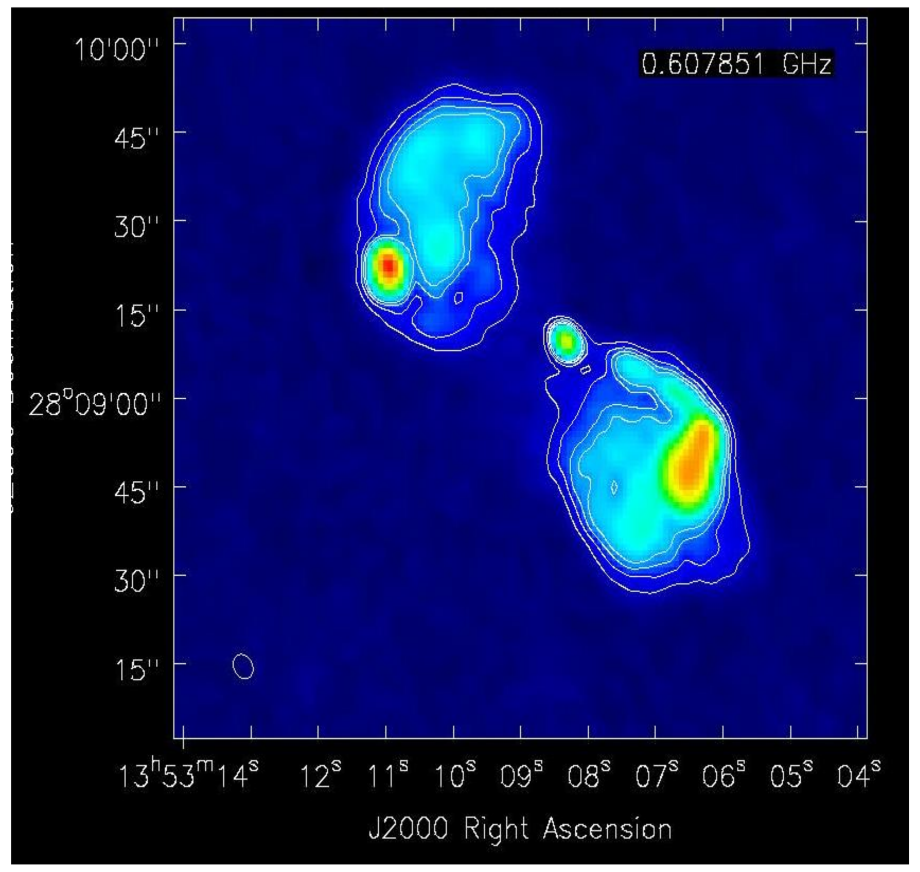

Fig 4. 610 MHz map of J1353+2809

References

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Precessing Jets of J2303−1841

- Among several S-shaped sources discovered so far, J2303−1841 is one of the clearest examples of precessing jets observed in QSO hosts[3].
- It has peculiar, concave radio spectrum, steep at low frequencies and flat at shorter wavelengths. This is typically observed for a compact flat-spectrum core surrounded by steep spectrum extended emission[4].
- In Fig 5, 608 MHz uGMRT image of J2303−1841 clearly reveals diffuse emission towards the north-east and south-west direction extended up to ∼3′ in the sky plane.
- High resolution 5 GHz observation provides a direct proof for a nodal structured jet's precession.

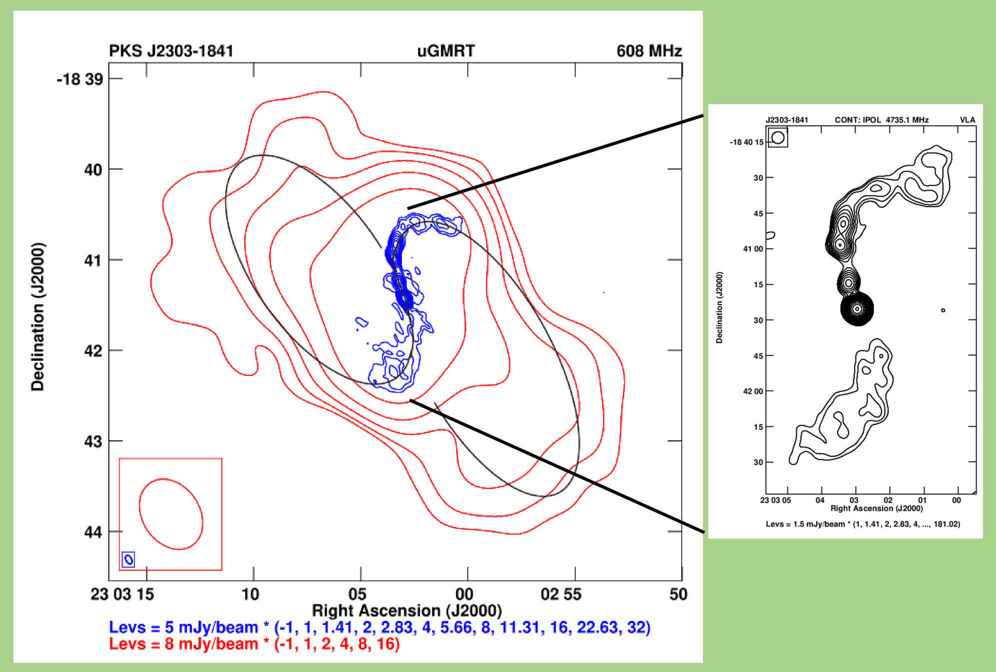

Fig 5. 608 MHz uGMRT map of PKS J12303−1841.Blue: original map with resolution 6.01" x 3.71", contour values selected to visualize well the inner compact emission. Red: tapered (3.5 x 3.5 klambda) map with the resolution of 49.91" x 37.88", contour values selected to visualize well the extended diffuse emission of the protrusions. Shape of the beams are marked in the lower left corner. The solid line represents the plasma distribution predicted by the precessing jet model. 5 GHz map (right panel) reveals the innermost structure of the radio source with a bright core and twisted jets.

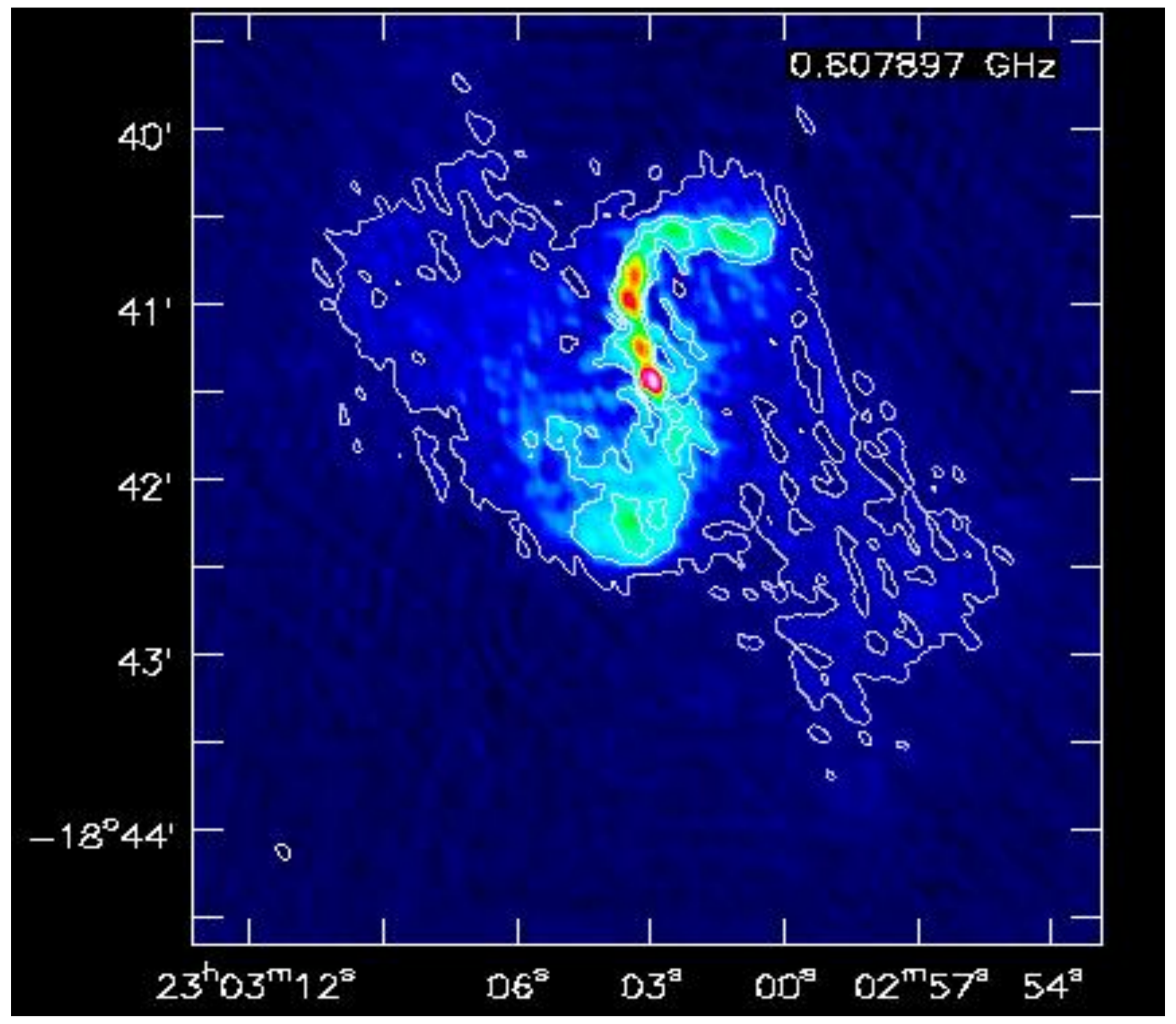

Fig 6. 610 MHz map of J2303−1841

- In Fig 6, the south east protrusions indicate jets being dragged from their previous position creating the twisted pattern of jets. The core and clear hotspots in the north-south direction indicate the current orientation and fresh activity of the source.
- The source J2303−1841, with associated redshift z = 0.128 has angular size of 4'.
- The total flux of the source at 610 MHz is 2.26 Jy.
- The total flux of the diffuse emission is 0.5 Jy.
- The spectral index of the diffuse emission between 610 MHz and 1400 MHz is 1.3, indicating a very steep spectrum.

Conclusions

- The jets show an S- shaped morphology, tracing old and new direction of plasma flow indicating jet precession.
- This study hence would be beneficial for observing steep spectrum "old" low energy particles present in the diffuse lobes to study precession.
- Our project is an attempt towards understanding the cause behind the morphology of some of the peculiar sources with the help of low frequency observations.
- Future work involves multifrequency observations of the target sources with spectral ageing analysis on independent section of the jets and of the area of diffuse emission.

Questions and comments are welcome. Please send them to the following address: arpita.misra@doctoral.uj.edu.pl